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Dated 22 December 2004

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

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1. Your reference — P36034-/SSI/CCI/KJO

2. Patent application number *(The Patent Office will fill this part in)* — 0329612.6 — 2 0 DEC 2003

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — Lloyd (Scotland) Limited
152 Bath Street
Glasgow
G2 4TB

   8776937001

   Patents ADP number *(if you know it)*

   If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention — SAFETY HELMET

5. Name of your agent *(if you have one)* — Murgitroyd & Company

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* — Scotland House
165-169 Scotland Street
Glasgow
G5 8PL

   Patents ADP number *(if you know it)* — 1198015

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request? — Yes

   Answer YES if:
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
   Otherwise answer NO (See note d)

Patents Form 1/77

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	
Description	11
Claim*(s)*	-
Abstract	-
Drawing*(s)*	4

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Murgitroyd & Company Date 19/12/2003

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

CHRIS CAIRNS 0141 307 8400
chris.cairns@murgitroyd.com

Warning

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Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) Part 7 should only be completed when a divisional application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entitlement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlier UK application, you should also complete part 6 with the priority details.

Safety Helmet

The present invention relates to safety helmets. In particular, but not exclusively, the invention relates to the energy absorbing materials used in safety helmets, and methods of forming such materials.

Crash helmets conventionally comprise a substantially spheroidal outer skin of tough plastics material and an inner skin of resilient material such as a hard foam. The rigid outer skin transmits an impact load more evenly to the inner skin which absorbs the energy imparted by the impact load. The helmets are formed in a female mould, or around a male mould, and the materials must undergo significant curvature to form the spheroidal shape. Also, the outer and inner skins must be inserted separately to the mould. Otherwise, during bending, the bond between the two materials would prevent the necessary slippage of the outer skin (which is stretched) relative to the inner skin (which is

compressed), or else would produce high planar stresses at the internal and external surfaces.

It may be desirable to decrease the total mass of the helmet. Also, the methods of forming the helmets, which typically involve hand lay-up, tend to be complex and expensive. It would be advantageous to be able to insert the inner and outer skin as a one-piece material within the mould.

Axially loaded columns of various cross sectional shapes have been used for some time to improve the structural crashworthiness of vehicles, roadside furniture and the like. Metal columns exhibit a multiple buckling and folding failure mode which is effective in absorbing impact energy. Plastic and composite columns have a number of failure modes but all of the modes typically involve progressive crushing of one end of the column.

The performance and failure mode of plastic and composite columns depends on a complex interaction of a number of different parameters including the material used, the geometry (shape and thickness), fibre alignment in composites, the use of triggers, and the loading conditions. However, a careful selection of these parameters can result in a safety device which outperforms the metal equivalent.

Regardless of the material used, arrays of columns arranged parallel to the load have generally been found to increase energy absorbing performance and

improve the stability of the safety device. Columns tend to produce a relatively constant level of energy absorption as the column is progressively buckled of crushed. Axially loaded cones have been found to produce a more linearly increasing rate of energy absorption which can often be more desirable in crash situations.

Sandwich panels, consisting of two tough outer skins separated by a core material having a lower stiffness, have been used in many applications such as building components and structural panels for road vehicles and aircraft. A popular core consists of a honeycomb structure, that is an array of longitudinal members, each member having a hexagonal cross-section. The axis of each longitudinal member is normal to the plane of the inner and outer skins and each end of each longitudinal member is typically bonded to the respective skin. Therefore, the honeycomb structure represents an array of columns arranged parallel to a load which impacts the plane of one of the outer skins.

WO 94/00031 discloses a safety helmet which includes a honeycomb sandwich structure. Generally, a hand lay-up method is used. EP 0881064 discloses a protective element which also has a honeycomb sandwich structure. The document states that the element may be incorporated within a wide range of protective clothing which includes helmets.

Honeycomb structures are suitable for applications involving flat panels or structures with only a relatively small curvature. However, problems arise when the material is used in items having a large curvature such as helmets.

Each hexagonal cell of the honeycomb structure has a rotation symmetry angle of $n.60^\circ$. The cell therefore does not have rotation symmetry about an angle of 90°. The cell is therefore not orthotropic, that is it has a different response to a load applied at a first angle than to a load applied at a second angle which is applied at 90° from the first angle. When forming a helmet, the material is bent around a mould about two orthogonal axis to form the spheroidal shape. Therefore, a hexagonal structure can create difficulties when trying to achieve the curvature desired.

Furthermore, a hexagonal structure is by nature anticlastic, in that a positive curvature about an axis results in a negative curvature about an orthogonal axis (the shape of a saddle illustrates this phenomenon). This again leads to difficulties in the forming process.

According to a first aspect of the present invention there is provided a safety helmet comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

The term "tube" is used to denote a hollow cylindrical or conical structure, preferably a circular cylindrical or circular conical structure. The tubular array results in a material which is substantially isotropic and substantially non-anticlastic.

Preferably each tube has a diameter of between 2 and 8 mm.

Preferably the first material comprises polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone. Preferably the material comprises Tubus Honeycombs™.

According to a second aspect of the present invention there is provided a liner for a safety helmet, the liner comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

According to a third aspect of the present invention, there is provided a safety helmet comprising:

a first material bonded to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

Preferably the first and second materials are in a softened state at the melt temperature of the adhesive. This allows thermoforming of the helmet

at the melt temperature of the adhesive, as the melted bond allows relative movement between the first and second materials.

Preferably the first material is one of a polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone material.

Preferably the second material is a plastics material, such as polyetherimide. Preferably the second material is a fibre reinforced plastics material. Preferably the fibres are made from glass or carbon.

Preferably the adhesive is a thermoplastic. Preferably the adhesive is a polyester based material.

Preferably the melt temperature of the adhesive is less than 180°C. Preferably the melt temperature of the adhesive is between 120°C and 140°C.

Preferably the helmet is heated during forming to between 155°C and 160°C.

Preferably the helmet further comprises a third material and the first material interposes the second and third materials. Preferably the first material is bonded to the third material using the adhesive.

Preferably the first material has an array of energy absorbing cells, each cell comprising a tube.

According to a fourth aspect of the present invention there is provided a method of forming a safety helmet comprising:

bonding a first material to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

Preferably the method includes selecting first and second materials which are in a softened state at the melt temperature of the first material.

Preferably the method includes hating the helmet during forming to between 155°C and 160°C.

Preferably the method includes bonding the first material to a third material using the adhesive.

Preferably the first material has an array of energy absorbing cells, each cell comprising a tube.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of the safety helmet;

Fig. 2 is a side view of the sandwich panel used to form the helmet of Fig. 1;

Fig. 3 is a side view of the sandwich panel of Fig. 2 in a curved state;

Fig. 4 is a plan view of a known arrangement of cells used for the core of a sandwich panel.

Fig. 5 is a plan view of a tubular array of cells used in the sandwich panel of Fig. 2;

Fig. 6 is a sectional side view of the tubular array of Fig. 5 in a curved state;

Figs. 7a, 7b and 7c are exaggerated plan views of positions of the tubular array of Fig. 6 which are compressed, neutral and extended respectively;

Fig. 8 is a side view of the heating process used for the sandwich panel of Fig. 2;

Fig. 9 is a cross sectional side view of a mould used in conjunction with the sandwich panel of Fig. 2; and

Fig. 10 is the sandwich panel of Fig. 2 in a moulded state.

Referring to Figs. 1 to 3, there is shown a safety helmet 10 formed using a panel 12 which comprises a first material or core 20 which is sandwiched by a second material or outer skin 30 and a third material or inner skin 50. Each of the outer 30 and

inner 50 skins are bonded to the core using an adhesive 40.

Fig. 3 shows the sandwich panel 12 in a curved state. In such a state, the material varies linearly from a state of zero stress (in respect of the major planes of the panel 12) at the neutral axis 14 to a state of maximum tensile stress at the exterior face of the outer skin 30 and a state of maximum compressive stress at the interior surface of the inner skin 50. These tensile and compressive stresses cause tensile and compressive strains respectively. Therefore, there is slippage between the outer skin 30 and the core 20 and the inner skin 50 and the core 20 unless this slippage is prevented by the adhesive 40.

A known core structure is a honeycomb or hexagonal arrangement which is shown in Fig. 4. Each hexagonal cell 60 has a rotation symmetry angle 62, 64 of 60°, 120° and so on, or in other words of $n.60°$, where n is an integer. Therefore, the cell does not have a rotation symmetry angle of 90° and so the overall material is not orthotropic. Also, the material will be anticlastic.

Fig. 5 shows an array of cells for the core material 20 according to the invention. Each cell comprises a tube 22. The tubes 22 are arranged in a close packed array such that the gap between adjacent tubes is minimised. Since each tube 22 has an infinite rotation symmetry angle, the overall

tubular array results in a material which is substantially isotropic and non-anticlastic.

Fig. 6 shows the tubular array in a curved state. As described above, the planar stress and strain at the neutral axis 14 is zero and so each tube 22 retains its circular shape as shown in Fig. 7a. At the inner surface 24, the tubes 22 will be compressed in the direction of the curvature, and the profile of the tubes at this position is shown in exaggerated form in Fig. 7b. At the outer surface 26, the tubes will be elongated in the direction of curvature and the profile of the tubes at this position is shown in Fig. 7c.

It should be noted that, despite compression and extension of the tubes 22, the profile of the tubes 22 when averaged through the thickness of the material 20 will be as found at the neutral axis 14. Also, if there is curvature about an orthogonal axis, this will tend to cause compression and extension in an orthogonal direction, tending to cause the profile of the tubes 22 at any point through the thickness to be as found at the neutral axis 14, although the diameter of the tubes 22 will be reduced at the inner surface 24 and enlarged at the outer surface 26. The tube will in effect be a cone which may even improve the energy absorbing capability of the structure.

The helmet is formed using a suitable thermoforming process. As shown in Fig. 8, the sandwich panel 12

is heated using heaters 70 to a temperature of between 155°C to 160°C, which is above the melt temperature of the adhesive 40.

The sandwich panel 12 is then transferred to a mould as shown in Fig. 9. The male portion 72 of the mould typically has a rubber contacting face and the female portion 74 is typically constructed from aluminium. The mould is at ambient temperature and the transfer of the panel 12 should be effected quickly, preferably in less than 6 seconds to minimise cooling of the panel 12. The male part 72 is then driven towards the female part 74 so that the panel 12 assumes the shape of the mould.

Since the panel 12 has been heated to above the melt temperature of the adhesive, slippage can take place between the outer skin 30 and the core 20, and between the inner skin 50 and the core 20. Cooling of the panel 12 to a temperature below 50°C ensures that the panel has assumed the curved profile and the adhesive once again bonds each of the skins 30, 50 to the core 20. The two parts of the mould can now be separated. The curved panel 12 is shown in Fig. 10.

Various modifications and improvements can be made without departing from the scope of the present invention. For instance, the tubes of the array may be conical and have a cone angle of any angle.

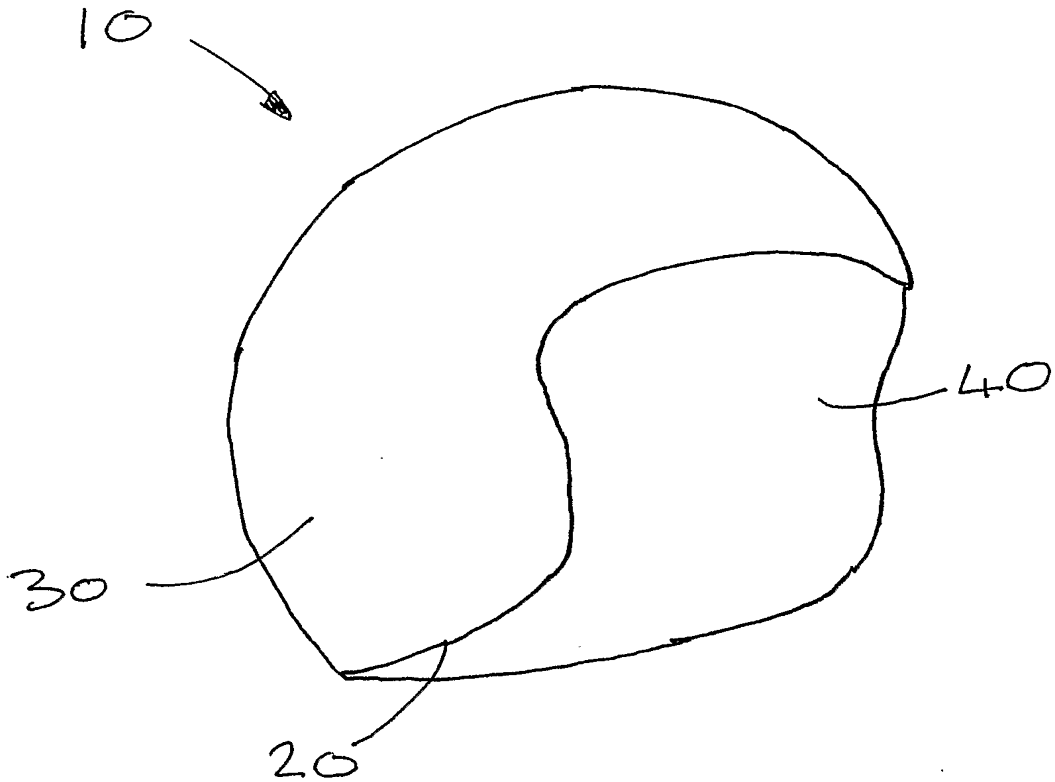


Fig 1

Fig 2

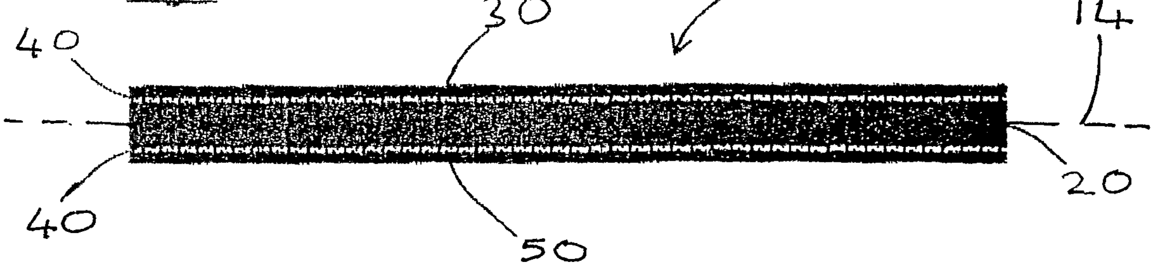


Fig 3

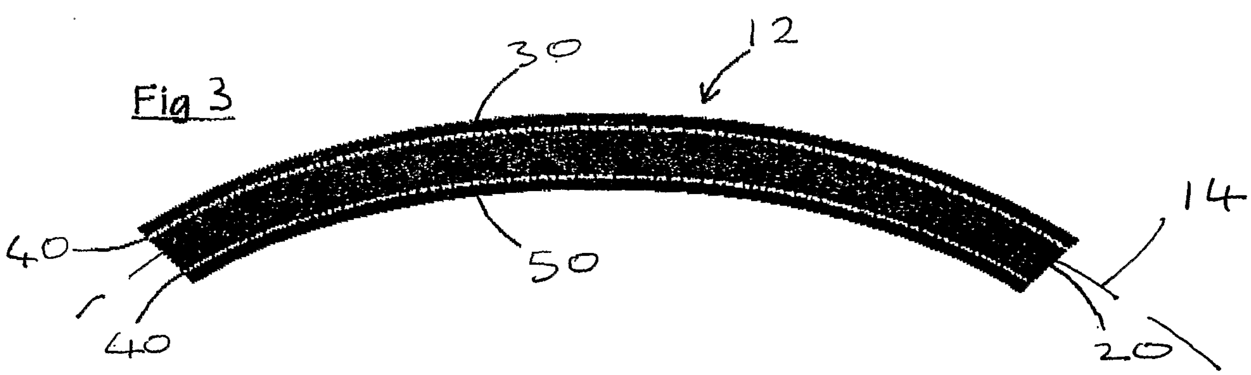


Fig 4

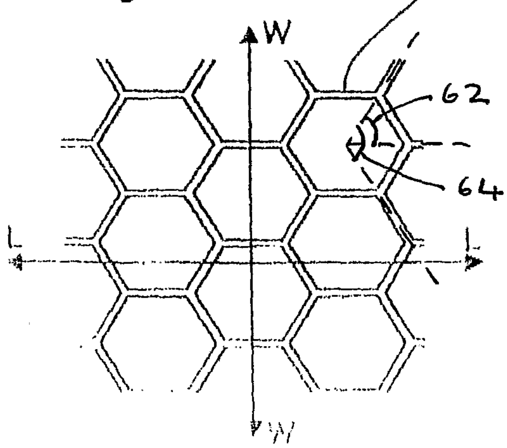


Fig 5

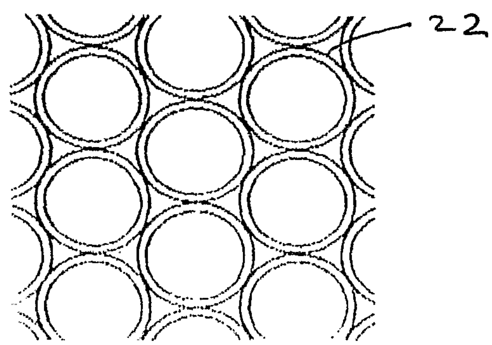


Fig 6

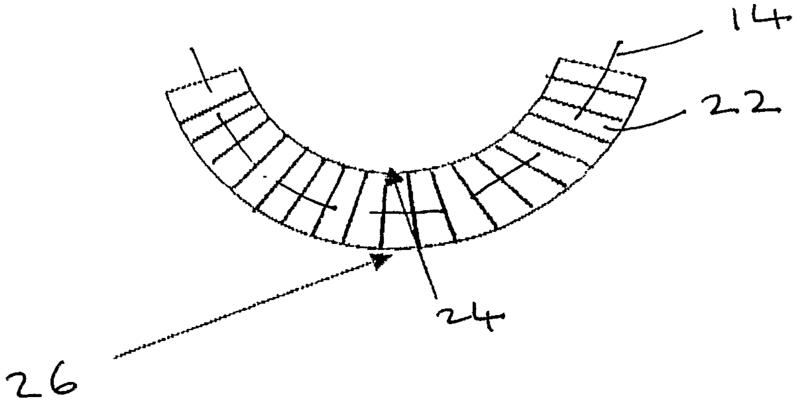
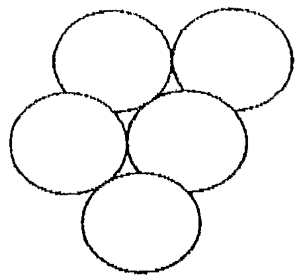


Fig 7a



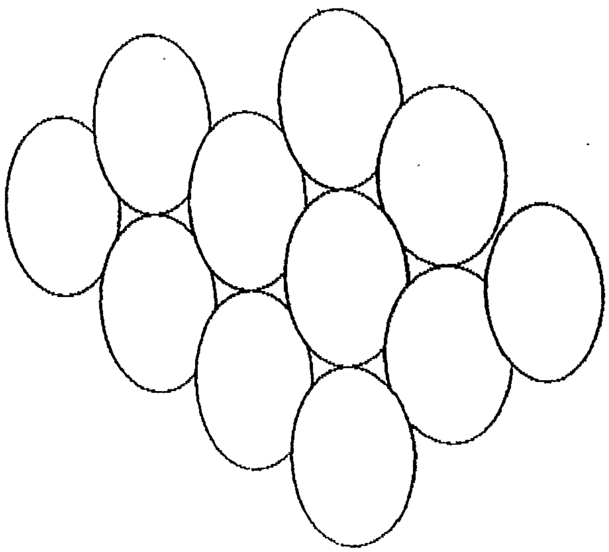


Fig 7b

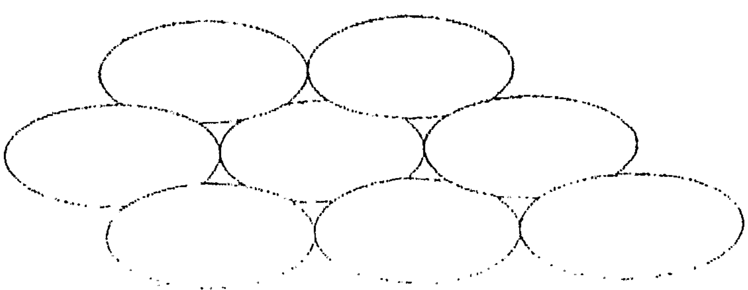


Fig 7c

Fig 8

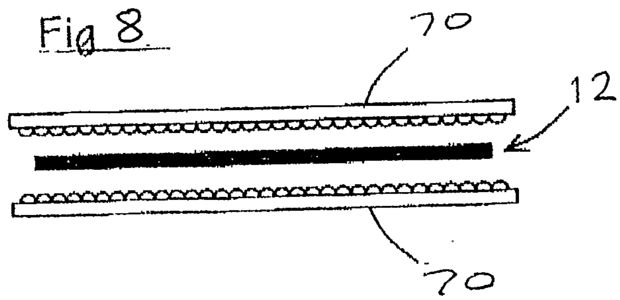


Fig 9

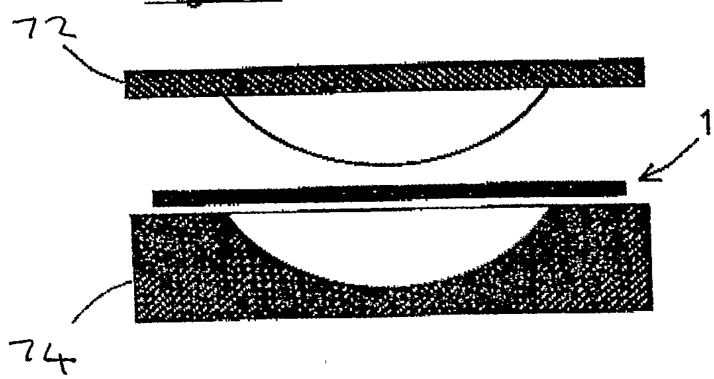
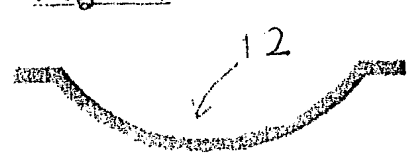


Fig 10



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